Fabrication and Performance Analysis of a Vertical Axis Wind Turbine for Ac Power Generation

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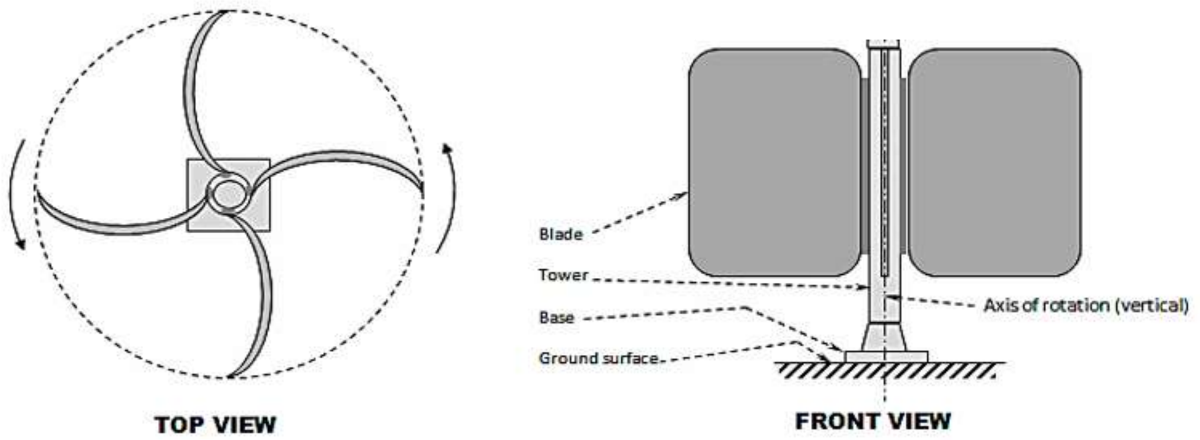
ABSTRACT:

Vertical axis wind turbines (VAWTs) represent a compelling avenue for wind energy harvesting, offering distinct advantages in specific deployment scenarios. With clear benefits in certain deployment situations, vertical axis wind turbines (VAWTs) are an attractive option for wind energy collection. VAWTs do not require complicated yaw systems, in contrast to their horizontal axis equivalents, because they can capture wind from any direction. Because of their omnidirectional capabilities, they are especially well suited for windy conditions, like those prevalent in cities. Additionally, maintenance operations are made simpler by the generator and gearbox being located at ground level. The optimization of VAWT blade designs, including both Darrieus and Savonius configurations, is the subject of ongoing study in order to improve power output and aerodynamic efficiency. Research also examines the structural soundness of VAWTs, tackling issues with fatigue and dynamic stall. Although VAWTs are a viable option for off-grid and dispersed generation applications, further design and material developments are essential to optimizing their potential and resolving current drawbacks.
Keywords: VAWT, Renewable Energy, Power output, AC Generation, DC Motor, LED Illumination, Wind Energy, Vibration.

INTRODUCTION:

Natural resources that are continuously renewed and accessible in a variety of forms, including sunshine, wind, ocean waves and currents, biomass and biofuels, geothermal sources, and hydropower, are the source of renewable energy [1]. In addition to the fact that there is a finite amount of fossil fuel storage on Earth, burning coal, oil, or gas to generate conventional energy has a negative environmental impact, making a swift and sustainable transition to renewable energy essential [2]. Reduced greenhouse gas emissions and global warming, improved public health, inexhaustibility with resilience and dependability, stable energy pricing, social development in terms of job creation, and more are just a few benefits of employing renewable energy resources [3].



An increasingly well-liked, renewable, and ecological energy source for producing power is wind energy. On average, wind has provided around 6% of global electricity in recent years [4]. When compared to other renewable energy sources, wind energy has been found to be the most ecologically benign, with the lowest water consumption requirements and the greatest social impacts [5,6]. Numerous separate wind turbines that are connected to the electrical power transmission network make up wind farms. Adequate power management strategies with anticipated weather variation are crucial since wind speed varies with time and space. The kinetic energy of wind is converted into electrical energy by a robust device equipped with mechanical, electrical, and structural components, termed a wind tur bine (WT). Due to a fair availability of steady and continuous wind speed, offshore regions are mostly preferred to install WTs. Statistical analysis reveals that the mean annual offshore wind speed may vary in the ranges of 12–13 m/s; thus the average angular speed of WT propellers usually varies between 10 and 20 rpm [7].

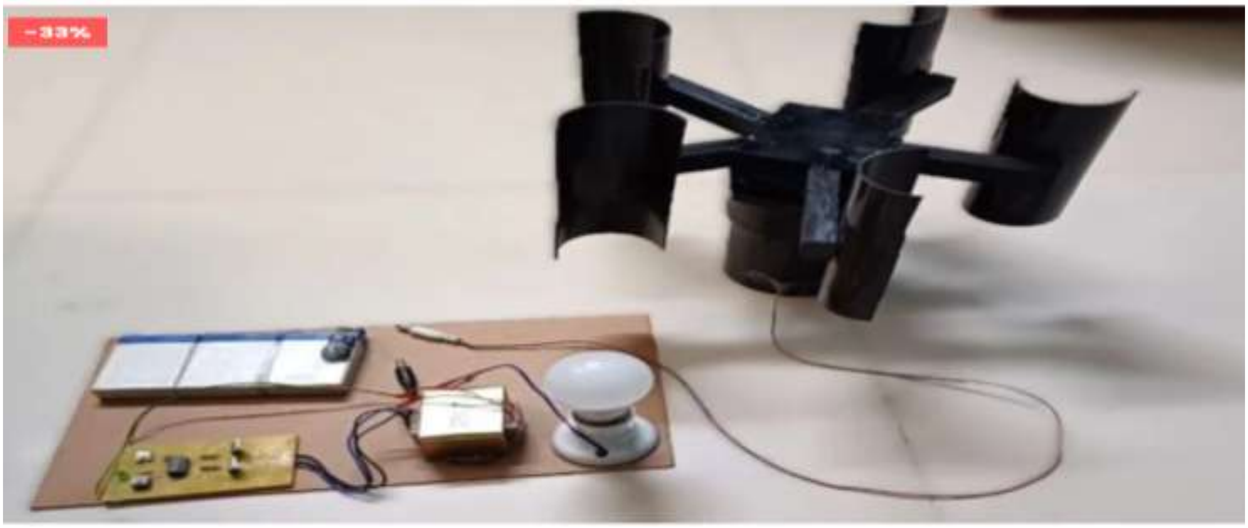
Wind Turbines

The device that is used to generate this non-conventional and clean source of energy from wind is known as a Wind Turbine or Windmill. Extraction of energy from wind is the primordial function of wind turbines. Aerodynamics naturally is an important aspect related to wind turbines. These are of different types based on various energy extraction methods. Overall the aspects of aerodynamics depend largely on the geometry. However there are some fundamental concepts that can be applied to all turbines. Each topology has a limiting maximum power for a given flow, and certain topologies are superior to others. The method used to extract power has a strong influence on this. In general all turbines can be grouped as being lift based, or drag based with the former being more efficient. The difference between these groups is the aerodynamic force that is used to extract the energy.

1.DESCRIPTION OF VERTICAL AXIS WIND TURBINE PROCESS

The kinetic energy of wind is transformed into rotating mechanical energy around a vertical axis by vertical axis wind turbines (VAWTs). VAWTs may receive wind from any horizontal direction, in contrast to horizontal axis wind turbines (HAWTs), which need a yaw mechanism to align with the wind direction. Their design, which usually uses airfoils or blades that revolve around a vertical shaft, gives them this omnidirectional capability. Wind causes variations in air pressure on opposite sides of these blades as it passes over them. he blades revolve because of the lift created by this pressure differential, which is comparable to an airplane wing.

After that, a drive train which could include a gearbox transfers the rotational motion to a generator. This mechanical energy is transformed into electrical energy via the generator.



To capture wind energy, several VAWT designs—such as the Darrieus and Savonius types—use different blade profiles and mechanisms, each with unique properties and levels of efficiency. The Darrieus type employs lift, like an airplane wing, while the Savonius type uses drag, where the wind pulls the blades[8].

2.MODELS OF VERTICAL AXIS TURBINE

The two primary types of VAWT models are Darrieus (lift-driven, more efficient) and Savonius (drag-driven, simple, good low-wind start, less efficient). Curved-blade (eggbeater form), helical (twisted blades), and H-rotor (straight blades) are Darrieus varieties. There are hybrid designs that combine different aspects. Designs differ in terms of drivetrain, size, and blade profile.

Savonius wind turbine

These turbines are among the most basic self-starting VAWTs, nonetheless. They are drag-type devices with two or three scoops in terms of aerodynamics. The Savonius turbine rotates as a result of differential drag. Long helical scoops are used in some designs to provide smooth torque.

A Savonius rotor's swept area is mostly close to the ground, which reduces the efficiency of energy extraction overall because wind speed is lower at lower altitudes. Savonius claims that the prototype's maximum efficiency was 37%, whereas the best of his rotors had a maximum efficiency of 31%[9]. The ventilator, a cooling device frequently found on the roofs of vans and buses, is the most popular use of the Savonius wind turbine.

Darrieus wind turbine

Beginning at the end of the 19th century, attempts to produce electricity increased in frequency over the first half of the next century. As seen in Fig. 2(b), the most well-known and widely used VAWT type that still goes by his name was created and patented in 1925 by French engineer G.J. Darrieus. One kind of VAWT that uses wind energy to create electricity is the Darrieus wind turbine. Darrieus wind turbines are ideal for small pumps and electrical generators because they can revolve quickly while producing little torque. Less than 10% of Darrieus-type turbines are efficient.

These designs' primary benefits are that the torque produced is nearly constant over a sizable angle and that they can self-start by pitching the "downwind moving" blade flat to the wind, which creates drag and begins the turbine spinning at a low speed. The wind-direction sensor must be included in order to pitch the blades correctly, and the blade pitching mechanism is complicated and typically hefty. Generally speaking, combining the rotor is one of the numerous strategies to maximize and get around the Darrius wind turbine's low starting torque issue[10].

3. INSTALLATION OF VERTICAL AXIS WIND TURBINE

Atypical small-scale model of a vertical-axis wind turbine with all mechanical, electrical, and structural accessories was collected from the manufacturer. They comprised the base plate, shafts, blades and their accessories, electrical generator and circuit, etc. As explained in the paper, after these separate parts were put together, in-depth parametric studies were carried out. Nonetheless, the authors concur that even for small-scale model turbines, a prototype design is necessary, and this is being done in subsequent studies [11].

Mechanical components

The schematic diagrams and photographic views of the installed vertical-axis wind turbines are portrayed in Figure. As observed, the rotor hub was attached to the tower shaft by means of a telescopic connection with a ball bearing to minimize the frictional resistance during rotation. Four equally spaced PVC blades were connected to the rotor hub, each of which being a circular arc with an inner radius and a semi-arc angle of 45; Curved-type multi-blades made of PVC were utilized in the model vertical-axis wind turbine used in the study, Because of its superior corrosion resistance, low weight, and enough strength and stiffness, finds extensive application in a variety of industries, including automotive, marine, military, and aerospace [12].

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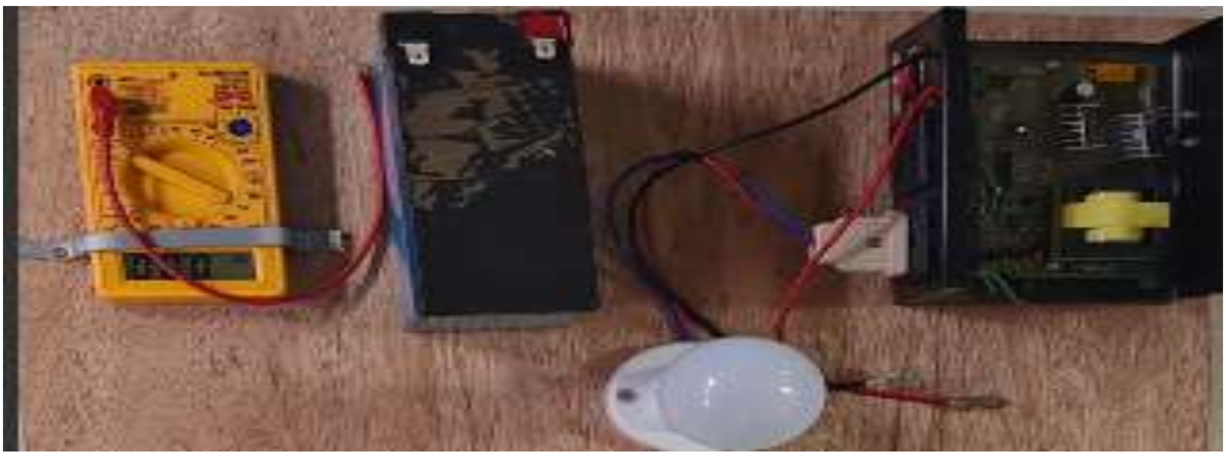
(a) Battery (b) Wind blade (c) Motor with gear

(d) inverter (e) Bulb

As a result, the wind turbine's overall weight is decreased while its durability is increased, which enhances its performance. The steel circle base, measuring 180 mm in diameter and 10 mm in thickness, is firmly attached to the tower shaft. The steel circular base is then attached to a hardwood square foundation, measuring 300 mm in diameter and 20 mm in thickness. The hardwood base is fastened to the lab floor with bolts for good. A pedestal fan that can run at low, medium, and high speeds created artificial air flow that started the shaft's spinning.

Electrical components

A DC motor, 12 V battery, DC inverter, switch, LCD, and transformer were in charge of the electrical system. In Figure 3, the electrical components' circuit diagram is shown. A dynamo transformed the rotor shaft's rotational energy into electrical energy, and the LCD monitor displayed the power output. The 12 V storage battery is charged by the system. The inverter converts the DC power output to AC when the battery is turned on, and the step-up transformer increases the voltage needed to operate the device; the transistor MOSFET controls this voltage. An industrial True RMS multimeter was used to test DC and AC voltages. The voltage needed to operate the device is increased by the transformer [13].



4. PERFORMANCE EVALUATION

The turbine has responded the wind speed in a reasonable way. With a wind speed of 5m/s, it has produced around 12V with deflectors. And also with a wind speed of 4m/s, it has produced around 10V with deflectors. It is a good improvement of the power value according to the performances of this Vertical axis wind turbine. The highest power values that generated by the turbine during the test is tabulate below.

Air flow speed by fan in m/s	blade speed in RPM	Volts in V
1	30	4
2	42	5.3
3	55	7.2
4	65	9.6
5	80	11.5

5. CONCLUSION

The VAWT system successfully converts wind energy into AC power, demonstrating its effectiveness for off-grid lighting solutions. The use of PVC blades, a steel frame, a gearbox, and a 12V generator ensures optimal performance. Experimental results confirm that voltage output increases proportionally with wind speed and RPM.Future improvements could focus on reducing aerodynamic losses, enhancing generator efficiency, and integrating advanced power storage systems. The study highlights the practical viability of VAWTs as an alternative energy source, offering a cost-effective and eco-friendly solution for remote power generation.

6. REFERENCES

1. Omar, E.; Haitham, A.R.; Frede, B. Renewable energy resources: Current status, future prospects and their enabling technology. Renew. Sustain. Energy Rev. 2014, 39, 748–764**.**

2. 2. 3. 4. 5. 6. 7. 8. 9. Shahzad, U. The need for renewable energy sources. Int. J. Inf. Technol. Electr. Eng. 2015, 4, 16–19.

3. Owusu, P.A.;Asumadu-Sarkodie, A. A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Eng. 2016, 3, 1167990. [CrossRef].

4. Enevoldsen, P.; Permien, F.-H.; Bakhtaoui, I.; von Krauland, A.-K.; Jacobson, M.Z.; Xydis, G.; Sovacool, B.K.; Valentine, S.V.; Luecht, D.; Oxley, G. How much wind power potential does Europe have? Examining European wind power potential with an enhanced socio-technical atlas. Energy Policy 2019, 132, 1092–1100.

5. Evans, A.; Strezov, V.; Evans, T. Assessment of sustainability indicators for renewable energy technologies. Renew. Sustain. Energy Rev. 2009, 13, 1082–1088.

6. Basack, S.; Goswami, G.; Dai, Z.-H.; Baruah, P. Failure-mechanism and design techniques of offshore wind turbine pile foundation: Review and research directions. Sustainability 2022, 14, 12666.

7. Cheng, M.; Zhu, Y. The state of the art of wind energy conversion systems and technologies: A review. Energy Convers. Manag. 2014, 88, 332.

8. S. Heier: Grid Integration of Wind Energy Conversion Systems. New York: John Wiley & Sons, Inc. (1988).

9. R. Gupta, S. Deka, R. Gautam, and R. Das, in : CFD Analysis of a two- bucket Savonius rotor for various overlap condition, ASME 5th International Conference on Energy Sustainability, August 7-10, 2011, Washington, USA (2011).
10. H. Iwashita, Y. D: Development of an Elastic Rotor-Blade for the Horizontal Axis WindTurbine: Proceedings of Wind energy symposium, pp. 187-190, (2004).
11. Aruri, D.; Adepu, K.; Adepu, K.; Bazavada, K. Wear and mechanical properties of 6061-T6 aluminum alloy surface hybrid composites [(SiC+ Gr) and (SiC+ Al2O3)] fabricated by friction stir processing. J. Mater. Res. Technol. 2013, 2, 362–369.
12. Ravikumar, S.; Jaswanth venkatram, V.; Sohaib, S.M. Design and analysis of wind turbine blade hub using aluminium alloy AA 6061-T6. Proc. IOP Conf. Ser. Mater. Sci. Eng. 2017, 197, 012044.
13. Choon, T.W.; Prakash, C.; Aik, E.A.; Hin, T.T. Development of low wind speed anemometer. Int. J. Adv. Sci. Eng. Inf. Technol. 2012, 2, 237–240. [CrossRef]